AP® Physics C: Electricity and Magnetism
2014 Scoring Guidelines

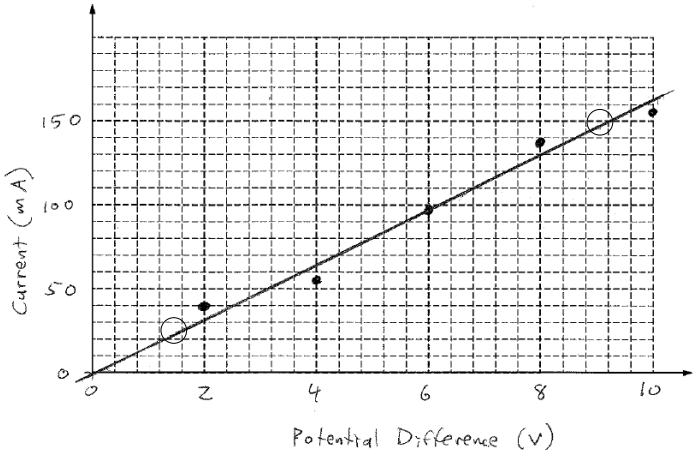
CollegeBoard

AP® PHYSICS C - ELECTRICITY AND MAGNETISM
2014 SCORING GUIDELINES

Question 1

15 points total **Distribution of points**

(a) 3 points



For labeling both axes with proper variables and units, and using appropriate linear scales for both axes — 1 point
For properly plotting the data points — 1 point
For drawing a reasonable best-fit straight line — 1 point

(b) 3 points

For calculating a slope using points on the line drawn in part (a), not data points unless they are on that line — 1 point

$$m = \frac{\Delta I}{\Delta V} = \frac{(150 - 25) \times 10^{-3} \text{ A}}{(9.2 - 1.6) \text{ V}} = 0.0164 \text{ A/V}$$

For correctly relating the slope to the resistance — 1 point

$V = IR$

$I = \frac{V}{R} = \frac{1}{R}V$

$\text{slope} = \frac{1}{R}$

$R = \frac{1}{\text{slope}} = \frac{1}{(0.0164 \text{ A/V})}$

For an answer with correct units consistent with the calculated slope — 1 point

$R = 61\ \Omega$

Note: linear regression yields a slope of 0.01565 A/V and an answer of $R = 63.9\ \Omega$

Question 1 (continued)

Distribution of points

(c) 2 points

For substituting the answer from part (b) into a correct equation to solve for R_1 — 1 point

For recognizing that R_2 and R_3 are in series — 1 point

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2 + R_3}$$

$$\frac{1}{R_1} = \frac{1}{(R_T)} - \frac{1}{(R_2 + R_3)} = \frac{1}{(61\ \Omega)} - \frac{1}{(50\ \Omega + 50\ \Omega)} = 0.0064/\Omega$$

$$R_1 = 156\ \Omega$$

(d) 2 points

For using a correct equation to solve for I_2 — 1 point

$$I_2 = \frac{V}{R_2 + R_3}$$

Substitute values

$$I_2 = \frac{(12\ \text{V})}{(50\ \Omega + 50\ \Omega)}$$

For a correct answer with units — 1 point

$$I_2 = 0.12\ \text{A}$$

(e) i. 1 point

For substituting proper values into a correct equation to solve for I_2 — 1 point

$$I_2 = \frac{V}{R_2} = \frac{(12\ \text{V})}{(50\ \Omega)}$$

$$I_2 = 0.24\ \text{A}$$

ii. 2 points

For selecting "Less than" — 1 point

For a correct justification — 1 point

Example: After a long time, the capacitor is completely charged and there is no current in the capacitor branch because the voltage across the capacitor is equal to the battery voltage, so there is no current through or voltage drop across R_2.

Note: If the wrong choice is selected, then no credit is given .

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Question 1 (continued)

Distribution of points

(f) 2 points

For selecting "Equal to" — 1 point

For a correct justification — 1 point

Examples:

Immediately after the switch is closed, the uncharged capacitor has no resistance to current or it acts like a wire. Therefore it does not affect the current through R_2.

The mathematical calculation in part (e)i does not depend on the value of C so changing the capacitance has no effect.

Note: If the wrong choice is selected, then no credit can be earned.

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Question 2

15 points total **Distribution of points**

(a) 2 points

	Position of Right End of Loop			
Speed of Loop	$L < x < 2L$	$2L < x < 3L$	$3L < x < 4L$	$4L < x < 5L$
Increases				
Decreases	✓		✓	
Stays the same		✓		✓

For selecting "Decreases" in the 1st and 3rd columns 1 point
For selecting "Stays the same" in the 2nd and 4th columns 1 point

(b) 4 points

For using a correct equation to solve for the emf 1 point

$\mathcal{E} = -\frac{d\phi}{dt}$

For a clear indication that the area is changing 1 point

$|\mathcal{E}| = B\frac{dA}{dt}$ or $|\mathcal{E}| = B\ell v$

Note: since the question asks for a magnitude, students are not penalized for excluding the minus sign for the emf.

For relating emf and current 1 point

$I = \frac{V}{R} = \frac{\mathcal{E}}{R}$

For a correct expression for the current 1 point

$I = \frac{BLv_0}{4R}$

(c) 2 points

For selecting "Counterclockwise" 1 point
For a correct justification 1 point
Examples:
As the loop enters the magnetic field, more of its area is in a magnetic field directed into the page. According to Lenz' law, this increase in flux will create a current with an opposing magnetic field that will be out of the page. Thus, the current must be counterclockwise.
As the loop enters the magnetic field, the combination of magnetic and electric forces on the charges in the right side of the loop will create a potential difference at the right side with the top being positive. This will cause the current to flow in a counterclockwise direction.
Note: If the wrong choice is selected, then no credit can be earned.

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Question 2 (continued)

Distribution of points

(d) 4 points

For a correct statement of Newton's second law 1 point
$F = ma$
For using a correct expression for the magnetic force 1 point
$F = I\ell B$
For substitution of variables into a correct expression for the net force, including a substitution for I consistent with the answer from part (b) 1 point

$a = -\frac{B\left(\frac{BLv}{4R}\right)(L/4)}{m}$

$a = -\frac{B^2L^2v}{16mR}$

For substituting dv/dt for a 1 point

$\frac{dv}{dt} = -\frac{B^2L^2v}{16mR}$

(e) 3 points

For selecting "Left" 1 point
For correctly stating that a clockwise current will be induced in the loop 1 point
For correctly applying the right hand rule to the current, field, and resulting force on the loop 1 point
Example: As the loop is leaving the field, the magnetic flux in the loop is decreasing. According to Lenz' law, a clockwise current is induced to oppose the change, which creates a magnetic field into the page. In the left end of the loop the current is up. By the right hand rule, the fingers point up in the direction of the current, the fingers cross into the direction of the magnetic field (into the page), and the thumb points left in the direction of the force.
Note: If the wrong choice is selected, then no credit can be earned.

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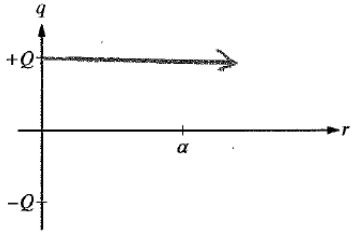
Question 3

15 points total **Distribution of points**

(a)

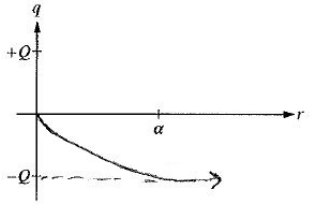
i. 2 points



For a graph that starts at $q = +Q$ 1 point

For a horizontal line (at $q = +Q$) 1 point

ii. 3 points

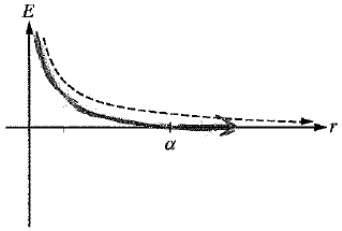


For a graph that starts at $q = 0$ for $r = 0$ 1 point

For a concave upward curve in the 4th quadrant between $r = 0$ and $r = \alpha$ 1 point

For a graph that approaches $-Q$ at $r = \alpha$ and equals $-Q$ beyond that point 1 point

(b) 2 points



For a graph that is decreasing and between the dashed curve and the x-axis 1 point

For a graph that goes to zero at $r = \alpha$ and is zero beyond that point 1 point

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Question 3 (continued)

Distribution of points

(c)

i. 3 points

For stating and using Gauss's law in any form 1 point

$$\oint E \cdot dA = \frac{q_{enc}}{\varepsilon_0}$$

For indicating that $q_{enc} = 0$ 1 point

For correctly stating that the electric field is zero 1 point

ii. 4 points

For indicating the need to integrate with respect to volume to find the negative charge enclosed 1 point

$$q_{neg} = \int \rho(r)\, dV$$

Substitute and integrate with appropriate limits

$$q_{neg} = \int_0^r -\frac{\beta}{r^2} e^{-r/\alpha} \left(4\pi r^2\right) dr = 4\pi\beta \int_0^r -e^{-r/\alpha}\, dr$$

$$q_{neg} = -4\pi\beta\alpha \left[-e^{-r/\alpha}\right]_0^r$$

For a correct expression for negative charge as a function of distance r 1 point

$$q_{neg} = -4\pi\beta\alpha\left(1 - e^{-r/\alpha}\right) \quad \text{or} \quad q_{neg} = 4\pi\beta\alpha\left(e^{-r/\alpha} - 1\right)$$

For including the $+Q$ when substituting for q_{enc} 1 point

For correct substitution for the surface area of a sphere 1 point

$$E\left(4\pi r^2\right) = \frac{q_{enc}}{\varepsilon_0} = \frac{Q - 4\pi\beta\alpha\left(1 - e^{-r/\alpha}\right)}{\varepsilon_0}$$

$$E = \frac{1}{4\pi\varepsilon_0 r^2}\left[Q - 4\pi\beta\alpha\left(1 - e^{-r/\alpha}\right)\right]$$

(d) 1 point

For correctly stating or implying that α is the radius of the atom or the radius of the electron cloud 1 point

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